58TH CONGRESS, 2d Session. } HOUSE OF REPRESENTATIVES. { DOCUMENT No. 307.

# HUDSON RIVER, NEW YORK.

## LETTER

FROM

## THE SECRETARY OF WAR,

TRANSMITTING,

**WITH A LETTER FROM THE CHIEF OF ENGINEERS, REPORT OF EXAMINATION OF THE UPPER HUDSON RIVER IN RELATION TO GORGES AND FRESHETS BETWEEN ALBANY AND COXSACKIE.**

JANUARY 4, 1904.—Referred to the Committee on Rivers and Harbors and ordered to be printed.

WAR DEPARTMENT,
*Washington, December 23, 1903.*

SIR: I have the honor to transmit herewith a letter from the Chief of Engineers, United States Army, dated December 14 instant, together with report of a Board of Engineers, dated November 13 ultimo, appointed pursuant to an item contained in the river and harbor act of June 13, 1902, making appropriation for the improvement of the Hudson River, as follows:

And the Secretary of War shall appoint a board of engineers to examine and determine whether existing Government work in connection with the Upper Hudson improvement causes gorges and freshets between Albany and Coxsackie; to report what changes should be made, if any, provided such is the case, together with an estimate of the cost thereof.

Very respectfully,

ELIHU ROOT,
*Secretary of War.*

THE SPEAKER OF THE HOUSE OF REPRESENTATIVES.

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WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
*Washington, December 14, 1903.*

SIR: The river and harbor act of June 13, 1902, in the item making appropriation for the improvement of the Hudson River, New York, contains the following provision:

And the Secretary of War shall appoint a board of engineers to examine and

determine whether existing Government work in connection with the Upper Hudson improvement causes gorges and freshets between Albany and Coxsackie; to report what changes should be made, if any, provided such is the case, together with an estimate of the cost thereof.

In pursuance of this provision a Board of Engineers was appointed on July 5, 1902, by authority of the Secretary of War, the Board consisting of Col. S. M. Mansfield, Maj. W. L. Marshall, and First Lieut. Edward H. Schulz, of the Corps of Engineers. On February 21, 1903, Colonel Mansfield, senior member of the Board, having been appointed a brigadier-general, U. S. Army, retired from active service and from duty with the Board.

Careful examination and consideration has been given the subject, and the discussions and conclusions of the Board are embodied in the accompanying report, dated November 13, 1903, which I now have the honor to submit for transmission to Congress.

The present approved project for the improvement of the Hudson River below Troy provides for a 12-foot channel, 400 feet wide, from Coxsackie to the foot of Broadway, Troy; thence gradually decreasing in width to 150 feet opposite the foot of Jacob street, Troy; thence 150 feet wide to the State dam, the estimated cost being $4,343,863. This is an extension of the original project adopted in 1867, the essential features of the plan of improvement being a system of longitudinal dikes, and accessory works, to confine the current and allow enough ebb and flow to keep the channel clear; together with dredging where rendered necessary by current conditions. Work under the existing project was begun in 1893, and at the present time the through channel from Albany to Coxsackie is 11 feet deep and 100 feet wide; from Albany to Broadway, Troy, the channel is generally 12 feet deep, with a least depth of 11 feet; above Broadway the channel depth is in various places considerably less.

Regarding the specific question which the act of June 13, 1902, requires to be determined, the Board expresses the opinion that the existing Government work in connection with the upper Hudson improvement has not only not caused gorges and freshets between Albany and Coxsackie, but that it has been an aid in diminishing them, and that the diking system should be extended to carry the channel over the bars, and to deepen and straighten the channel throughout the entire course from the State dam to Coxsackie. The Board is further of the opinion that gorges and freshets can not be completely overcome by any practicable rectification or deepening of the river, but recommends certain modifications in the channel improvement on the reach of the river between Albany and Coxsackie, which, if made, will remove some of the local objections to the diking system.

The estimated cost of the changes recommended by the Board is $113,300.

I concur with the Board in its conclusions and recommendations.

Very respectfully, your obedient servant,

G. L. GILLESPIE,
*Brig. Gen., Chief of Engineers, U. S. Army.*

Hon. ELIHU ROOT,
*Secretary of War.*

REPORT OF BOARD OF ENGINEERS ON EXAMINATION OF UPPER HUDSON RIVER, NEW YORK, TO DETERMINE WHETHER GOVERNMENT WORK THEREON CAUSES GORGES AND FRESHETS BETWEEN ALBANY AND COXSACKIE.

UNITED STATES ENGINEER OFFICE,
*New York City, November 13, 1903.*

GENERAL: The Board of Engineers constituted by Special Orders, No. 19, Headquarters, Corps of Engineers, July 5, 1902, has the honor to submit the following report upon the improvement of the Hudson River, New York, to comply with the requirements of the river and harbor act of June 13, 1902.

The special duty required of the Board in the language of the act was—

To examine and determine whether existing Government work in connection with the Uppper Hudson improvement causes gorges and freshets between Albany and Coxsackie; to report what changes should be made, if any, provided such is the case, together with an estimate of the cost thereof.

In accordance with the above act the Board was constituted by the following order:

SPECIAL ORDERS, No. 19.

HEADQUARTERS, CORPS OF ENGINEERS, UNITED STATES ARMY,
*Washington, July 5, 1902.*

*Extract.*

* * * * * * *

4. By authority of the Secretary of War, and in accordance with the provisions of the river and harbor act of June 13, 1902, a Board of officers of the Corps of Engineers, to consist of Col. Samuel M. Mansfield, Maj. William L. Marshall, First Lieut. Edward H. Schulz, will assemble at New York City, upon the call of the senior member, to examine and determine whether existing Government work in connection with the upper Hudson improvement causes gorges and freshets between Albany and Coxsackie, to report what changes should be made, if any, provided such is the case, together with an estimate of the cost thereof.

The Board is authorized to visit such points as it deems necessary for the proper performance of its duties.

Upon the completion of the duty assigned them the members of Board will return to their proper stations.

The journeys required under this order are necessary for the public service.

* * * * * * *

By command of Brig. Gen. Gillespie:

CHAS. S. BROMWELL,
*Captain, Corps of Engineers.*

Pursuant to the above order, the Board met at Albany on the morning of November 7, 1902, and, accompanied by Mr. R. H. Talcott, United States assistant engineer, made a careful examination of the river from the State dam, at Troy, to Stuyvesant, N. Y., covering the improvements. The water was at a normal stage, and the dikes and their construction and location were plainly noted. Scorings on trees and buildings were evident, and indicated the height of the ice during the freshet of March, 1902.

The Board again visited Albany on January 28 and 29, 1903. On January 28, after due advertisement, a public hearing was held in the city hall at Albany, at which all persons interested in the matter were requested to attend and to present their views. This hearing was largely attended, and stenographer's report[a] of the same taken, which is forwarded herewith.

[a] Not printed.

On February 20, Col. S. M. Mansfield, senior member of the Board, was appointed a brigadier-general, U. S. Army, and retired from active service and from duty with the Board on February 21, 1903.

The Board held a subsequent meeting at Albany, and inspected the scene of the gorges of February, 1903, on July 22, 1903.

At the hearing of January 28 there were present, in addition to the members of the Board, Mr. R. H. Talcott, United States assistant engineer; Mr. William Bayard Van Rensselaer, chairman, and Mr. William B. Jones, secretary, of the committee on freshets in Hudson River, of the Albany Chamber of Commerce. The Board is indebted to the above gentlemen for assistance in arranging for this hearing. At this time gorges had formed at Cow Island, above Castleton, and at Mulls Cross-over, opposite Clifford's ice house. Through the courtesy of the New York Central and Hudson River Railroad, the observation locomotive "Mohawk" was provided, and on January 29, accompanied by Messrs. Talcott, Van Rensselaer, Jones, and the officials of the railroad, the Board inspected the river from Troy to Hudson, making special observations at Cow Island, Castleton, Clifford's ice house on Upper Schodack Island, Stuyvesant, and opposite Lighthouse Island, examining the localities of present ice gorges and meeting and discussing matters with local interested parties.

## CHARACTER AND OBJECT OF THE IMPROVEMENT.

The improvement of the Hudson River by the State antedates the past century, but the part taken by the General Government began in 1834. The improvement contemplated the construction of longitudinal dikes from Troy to New Baltimore, supplemented by dredging. Occasional work was done from 1835 to 1838. A suspension of work then occurred, and active operations on a large scale were not resumed until 1867, under the project prepared by the officer then in charge.

Meanwhile the State of New York had constructed, between 1863 and 1867, six longitudinal dikes on the left bank from Houghtailing Island to Albany. Since then the diking has been done almost exclusively by the General Government, and the dredging by the State up to 1893. The plans adopted in 1867 provided for securing a navigable channel 11 feet deep at mean low water from New Baltimore to Albany and 9 feet deep at mean low water from Albany to Troy. A description of the plan is as follows:

First. A system of longitudinal dikes to confine the current and allow enough ebb and flow to keep channel clear, the dikes to be gradually brought nearer together from New Baltimore to Troy, their height to be approximately at level of tidal high water. (The dikes are actually about 1 foot above low water).

Second. The dredge to be used where necessary to open the channel, which the current should not be allowed to do, except very gradually.

Third. The side reservoirs to be kept open to the passage of tidal currents by gaps at their lower extremities in order to increase the tidal flow.

Fourth. Dumping dredged material in secure places.

Fifth. Constructing the dikes of timber and stone, and so designed as to admit of an increased height if necessary.

Sixth. Revetments where necessary, to prevent abrading action of the current.

Seventh. Limits to be prescribed beyond which no enroachments on the channel be made. Width between dikes and revetments to vary between 575 at Troy to 1,200 at New Baltimore, the average between Albany and New Baltimore to be 800 feet.

## PHYSICS OF THE HUDSON RIVER.

The Hudson River has its source in the Adirondacks, near Newcomb, Essex County, in 14 small lakes, 200 feet above tide water, and having an area of 6,000 acres. From the source to Fort Edward is 109 miles, and the drainage area to this point is 2,300 square miles. From Fort Edward to the State dam, at Troy, is a distance of 40 miles, with a difference of level of 108½ feet. The height of the dam being 9½ feet, the total difference of level between Fort Edward and tide water is 118 feet.

In the upper section there are numerous dams, with a succession of reaches of different level.

The drainage area below Fort Edward is 2,075 square miles, making a total above the State dam, exclusive of Mohawk Valley, of 4,375 square miles, or 2,800,000 acres. The Mohawk River drains an area of 2,800 square miles, or 1,814,000 acres, and joins the Hudson at Troy, making the total drainage area to Troy 7,200 square miles, or 4,614,000 acres. The greater part of the material carried in suspension comes from the Mohawk, while the heavy sands have come from the upper Hudson.

*Rainfall and water supply.*—The average annual rainfall during the past ten years, from observations recorded by the United States Weather Bureau at Albany, N. Y., is 34.52 inches; greatest yearly, 40.79 (1897); least yearly, 27.88 (1896); greatest monthly, 7.21 (August, 1893); least monthly, 0.56 (February, 1901). (Records are given to March 31, 1903.) The river rises almost immediately after a heavy rain. During the dry season of almost every year, for a month or over, very little water flows over the State dam. Navigation below the dam then depends on the tidal flow (range about 2 feet) and on the water leaking through the dam and used in lockage.

*Freshets.*—Mohawk River freshets are short and severe and more frequent than in the upper Hudson. The greatest freshet in the Hudson at Albany, due to rainfall alone, occurred in October, 1869, the water rising to a height of 19 feet, due to a rainfall in that month of 13 inches. The highest known rise of 22 feet, due to an ice gorge at Van Wies Point, occurred in February, 1857. The greatest rises may be expected after severe rains in the spring, when the ground is frozen and the drainage free. The effect of the freshets is to produce unusual scour in contracted channels and deposit the material at points where the cross section becomes enlarged. In order to limit the effect of freshets, the dikes provided in the project of 1867 have been kept below the level of ordinary tidal high water.

*Tides and discharges.*—The mean rise and fall of tides is as follows:

| | Range of tide. | | Plane of low water above low water at New York. | |
|---|---|---|---|---|
| | 1876. | 1899. | 1876. | 1899. |
| | *Feet.* | *Feet.* | *Feet.* | *Feet.* |
| State dam, Troy, N. Y. | 0.80 | 2.05 | 4.53 | 3.11 |
| Nail works, Troy, N. Y. | 1.94 | 2.92 | 2.98 | 2.28 |
| Albany, N. Y. | 2.32 | 2.81 | 2.43 | 2.31 |
| Castleton, N. Y. | 2.53 | 2.62 (95) | 2.13 | 2.18 (95) |
| New Baltimore, N. Y. | 3.42 | 3.19 (95) | 1.31 | 1.16 |
| New York, Governors Island | 4.40 | 4.38 (95) | ..... | ..... |

The tidal area from the dam to Albany measures 47,600,000 square feet. The tidal prism for a mean range of 2.5 feet is 117,000,000 cubic feet.

The area of cross section at Albany, with width of 850 feet, is approximately 10,000 square feet, and mean discharge 2,995 cubic feet per second. The mean combined discharge of Mohawk and upper Hudson in October, 1874, was 4,853 cubic feet per second. Information regarding velocities at different stages is not conclusive, but observations show that a freshet rise of 7 feet gives velocity of 3 feet; of 8 feet a velocity of 3¼ feet per second, and of 10½ feet a discharge of 85,000 cubic feet per second and a mean velocity of 4.8 feet per second. With a maximum rise the velocity does not exceed 6 feet per second. The discharge of the Hudson between Troy and Albany at the lowest stage is about 3,000 cubic feet per second.

The entire subject of the improvement of the Hudson River below Troy was carefully investigated by a Board of engineer officers, who reported on this matter October 1, 1891. (H. Ex. Doc. 23, Fifty-second Congress, first session.) This report is very comprehensive, and has been fully consulted for facts in the preparation of this report.

The present approved project, approved July 13, 1892, and amended March 3, 1899, provides for a 12-foot channel 400 feet wide from Coxsackie to the foot of Broadway, Troy; thence gradually decreasing in width to 150 feet opposite the foot of Jacob street, Troy; thence 150 feet wide to the State dam; estimated cost, $4,343,863. Work under this project was begun in 1893. At the present time the through channel from Albany to Coxsackie is 11 feet deep and 100 feet wide; from Albany to Broadway, Troy, the channel is generally 12 feet deep, with a least depth of 11 feet; above Broadway the channel depth is in various places considerably less.

The total appropriations for improvement of the Hudson River from—

| | |
|---|---|
| 1834 to 1890 | $1,667,938.00 |
| 1890 to 1902 | 3,303,506.56 |
| Total | 4,971,444.56 |

On June 30, 1902, there was a balance of $440,529.64, and the amount estimated for completion of the project was $1,040,356.44. The local commerce for 1901 amounted to 3,123,409 tons, and the number of passengers carried was 1,293,236.

The following table from the Annual Report of the Chief of Engineers for 1902, page 950, gives the width and depth of deepest navigable channel through the bars and shoals in 1902. Depths refer to mean low-water plane of 1876.

| Locality. | 1902. | |
|---|---|---|
| | Width. | Depth. |
| Coxsackie shoal | 50 | 10.5 |
| Stonehouse bar | 100 | 11.0 |
| Willow Island shoal | 300 | 12.0 |
| Coeymans Cross-over | 350 | 12.0 |
| Roah Hook to North Coeymans | 200 | 11.0 |
| Mulls Cross-over | 400 | 12.0 |
| Nine-Mile-Tree Cross-over | 250 | 11.5 |
| Castleton bar | 150 | 11.0 |
| Cedar Hill bar | 200 | 11.5 |
| Winnies bar | 200 | 11.5 |
| Stone Light shoal | 300 | 11.5 |
| Beacon Island shoal | 400 | 12.0 |
| Bogart Light shoal | 60 | 12.0 |
| Douws Point Cross-over | 200 | 12.0 |

| Locality. | 1902. | |
|---|---|---|
| | Width. | Depth. |
| Cuyler bar | 150 | 11.5 |
| Through draws of bridge at Albany | 110 | 12.0 |
| Bath Cross-over | 150 | 11.0 |
| Bath shoal | 200 | 12.0 |
| Kellogg shoal | 100 | 12.0 |
| Fishhouse shoal | 200 | 12.0 |
| Round shoal | 200 | 11.0 |
| Covill Folly | 150 | 12.0 |
| Opposite Breaker Island | 250 | 12.0 |
| Van Buren bar | 180 | 12.0 |
| Washington bar | 200 | 12.0 |
| Front of Watervliet Arsenal | 100 | 12.0 |
| Arsenal to Congress street | 300 | 12.0 |
| Congress street bridge draw | 100 | 11.5 |
| Congress street to Broadway | 400 | 11.0 |
| Broadway to Delaware and Hudson bridge | 200 | 10.5 |
| Delaware and Hudson bridge draw | 50 | 4.5 |
| Delaware and Hudson bridge to Hoosick street, Troy | 100 | 10.0 |
| Hoosick street to State dam | 50 | 5.5 |

The ice gorges and freshets which have occurred on the upper Hudson, as near as can be ascertained by the Board, are as follows:

| Year. | Month. | Elevation, mean low water 1876. | Location of gorge. |
|---|---|---|---|
| 1818 | Mar. 3 | | |
| 1832 | Mar. 12 | | |
| 1839 | Jan. 27 | 17.78 | |
| 1846 | Mar. 15 | 18.27 | G. At Barren Island. |
| 1851 | Feb. — | | |
| 1857 | Feb. 9 | 21.25 | D. At old dam above Van Wies Point. |
| 1861 | Feb. 13 | | |
| 1862 | Apr. — | | |
| 1865 | Mar. 18 | | |
| 1866 | Mar. 25 | | |
| 1869 | Jan. 11 | 18.00 | B. At New York Central and Hudson River Railroad freight bridge |
| 1869 | Apr. 22 | 19.00 | |
| 1869 | Oct. 4–5 | 18.52 | No ice. |
| 1876 | Feb. 16 | 14.00 | Do. |
| 1880 | Jan. 28 | | |
| 1882 | Feb. 24 | | C. At Douws Point. |
| 1884 | Feb. 14–15 | | D. At Van Wies Point, causing lower part of city to be flooded. |
| 1884 | Mar. 22 | | J. Broke at Van Wies Point and formed at Four-mile Point, between Coxsackie and Hudson; no dikes. |
| 1884 | Mar. 26 | | No ice. |
| 1885 | Jan. 1 | | C. On Overslaugh. |
| 1885 | Apr. 4 | | D. Ice from Mohawk River formed ice dam at Van Wies Point. |
| 1886 | Jan. 8 | | F. Between Castleton and Coeymans. |
| 1886 | Feb. 13 | | A. At Patroons Island, above Bath. |
| 1886 | Feb. 14 | 17.89 | B. In front of Albany. |
| 1887 | Apr. 5 | | A. At Patroons Island. B. At upper bridge. |
| 1887 | Apr. 12 | 15.00 | No ice. |
| 1888 | Apr. 1 | | G. At Barren Island, just below Coeymans. |
| 1891 | Mar. 14 | | |
| 1892 | Jan. 15 | | F. At Mulls Cross-over, above Coeymans. |
| 1893 | Mar. 13 | | C. On the Overslaugh, and ice piled to a depth of from 20 to 30 feet above Van Wies Point. |
| 1893 | Mar. 26 | 18.43 | H. Off south end of Houghtailing Island. |
| 1893 | May 5 | 16.12 | No ice. |
| 1893 | Dec. 9 | | I. Between Kinderhook upper and lower lights, and near Coeymans, F. |
| 1893 | Dec. 26 | | C. South of Albany and Greenbush bridge. |
| 1894 | Mar. 7 | | B. Mohawk River and upper Hudson ice gorged between railroad bridges at Albany, and from Cedar Hill to North Coeymans, F. |
| 1895 | Apr. 10 | 15.96 | No ice; melting snow and rain. |
| 1896 | Mar. 1 | 17.78 | J. As far down as Stockport, and remained fast until beginning of April. |
| 1898 | Mar. 13 | 13.30 | |
| 1899 | Mar. 6 | 12.45 | D. At Van Wies Point. E. Opposite Castleton. G. Below North Coeymans. |
| 1900 | Feb. 14 | 19.96 | I. Below Kinderhook upper light. F. Between Coeymans and North Coeymans. E. From north end of Castleton (U.S.) dike to Cow Island light. |
| 1901 | Dec. 12 | 13.58 | H. Below Stonehouse bar, New Baltimore. |
| 1902 | Mar. 2 | 18.50 | Do. |
| 1903 | do | 16.32 | E. At Cow Island, Castleton. F. Clifford's icehouse, Upper Schodack Island. |

Recapitulating the above freshets and considering only those aided by ice gorges, we have:

*Freshets caused by gorges.*

| Locality. | Number of freshets. | Date of last freshet. | Height of last freshet. |
|---|---|---|---|
| | | | *Feet.* |
| A. Above Bath (Patroons) | 2 | Apr. 5, 1887 | ..... |
| B. At and near Albany and railroad bridges | 4 | Mar. 7, 1894 | ..... |
| C. At Douws Point and Overslaugh | 4 | Dec. 26, 1893 | ..... |
| D. Near Van Wies Point | 4 | Mar. 6, 1899 | 12.45 |
| E. Castleton and Cow Island | 3 | Feb. 14, 1900 | 19.96 |
| F. Between Castleton and Coeymans and Mulls Cross-over, etc | 6 | Mar. 2, 1903 | 16.32 |
| G. At Barren Island | 3 | Dec. 9, 1893 | 12.45 |
| H. South end of Houghtaling Island and Stonehouse bar | 3 | Mar. 2, 1902 | 18.50 |
| I. Between Kinderhook upper and lower light | 2 | Feb. 14, 1900 | 19.96 |
| J. Below Coxsackie | 2 | Mar. 1, 1896 | 17.78 |

It appears from the above that the greatest freshet in conjunction with a gorge was at Van Wies Point in 1857—height, 21.25 feet—previous to the removal of rock by the United States at this point.

The greatest recent freshets were: February 14, 1900, rise 19.96 feet; March 2, 1902, rise 18.50 feet, and March 2, 1903, rise 16.32 feet.

The gorges of 1900 and 1902 at Stonehouse bar were formed below New Baltimore, where no diking had been done except at the north end of Bronks Island.

The gorge of 1903 formed between Clifford's ice house, Upper Schodack Island, and Roah Hook light. The tracing [a] herewith shows the positions of the gorges of 1903, and it will be noted that these gorges formed near cross sections numbers 9 and 10, at a curve of the river, and where the channel is very irregular and shallow. A description of these gorges and the methods adopted to break them up by means of armored boats is given in the report of the committee on freshets of the Hudson River (Appendix 4[a]).

The public hearing of January 28 was largely attended by representative bodies from localities along the river within the limits of the improvements. The following is taken from the papers presented at the hearing (Appendix 1[a]):

*Mr. John F. Lape, of Rensselaer, N. Y.*, attributes freshets to narrow and crooked channel, which has been contracted with the evident intention of making deeper water. The river has always been too narrow in several places below Albany. Worst places are at Barren Island and Van Wies Point. Expects no redress until river is widened, deepened, and straightened. Quotes Captain Little, who says Lamp Island dike is a poor construction, for the reason that the ice is thrown over to New Baltimore. Finds Kinderhook upper and lower lights one of worst places on river. Prospect Grove to Rattlesnake Island also very bad.

At the close of hearing Mr. Lape presented a resolution that the General Government should improve the Upper Hudson by a channel free from bends and crooks, 800 feet wide and 15 feet deep at mean low water, with a request to present the resolution to Hon. Elihu Root, Secretary of War.

*Mr. W. E. Scott, of Castleton, N. Y.*, says dikes cause gorges; instances Barren Island and other places; wishes removal of obstructions (dikes).

*Mr. N. J. Spaulding, of Schodack Landing, president of State transportation reform association, and Mr. J. M. Clute, marine engineer*, call for—

First. The removal of obstructions in the west channel by cutting away Barren Island and excavating rocks on Coeymans side of channel and in bed of river.

[a] Not printed.

Second. Open Schodack Creek; favors the second as less expensive; says dikes have not materially increased danger, but rather have lessened it; thinks dike between Castleton and Schodack Island to Zeigler Island (Mulls Plaat), cutting off Schodack channel, has added to danger of floods and gorges.

*Mr. John N. Briggs, of Coeymans*, has seen more destructive ice gorges prior to 1867 than since except that of 1902, which was about 1 foot higher than those of 1846 and 1868, but not so destructive; thinks river improvements can not be charged with causing gorges except at lower end of Coeymans channel, where it is narrowed by Middle Ground dike and West Shore dike; suggests removal of 100 feet of lower end of Middle dike, also removal of jetty (Lamp Island dike) near New Baltimore and its surrounding shoal and possibly removal of top of easterly portion of drowned lands above Bronks Island on west side near Stuyvesant upper light, which would remove an obstruction against which ice gorges often form, and where most extensive gorges have formed in the past forty years; suggests a depth of water along channel bank of 5 feet at low water, with a gradual rise of bottom to Bronks Island Creek dike, where a gorge might form.

*Mr. F. W. Orr, of Troy, chairman of Troy freshet committee*, says gorges are the result of small freshets; if these can be prevented there will be no great freshets later; dikes not responsible; they are mere incidents in the general results. Problem to be solved is the impounding of the water that would make a freshet as great as 60 inches on the Troy dam; in other words, impound the water in reservoirs, which would flow over the Troy dam from 48 to 60 inches on dams.

*Petitioners of Stuyvesant, N. Y.*—Gorges are due to the formation of sand bars; chief one is one-quarter mile below Stuyvesant. The cure is to open up the eastern channel in its natural direction.

*New York Central and Hudson River Railroad.*—Exhibit B shows gorges from 1850 to 1902; the locality and increasing severity are coincident with dike extension; suggests dikes are the cause of the present gorge between Barren Island and North Coeymans, about 2 miles long, and between Castleton and Cow Island. In February, 1902, there was a gorge north and south of Stuyvesant similar to the present one. High water from the Mohawk caused an ice dam north of Castleton, flooding railroad tracks. Dam formed again south of Schodack, possibly where it is now; this broke and formed again between Nutten Hook and Stuyvesant light.

In 1896 there were similar gorges; final dam seems to have formed on bar at mouth of Stockport Creek.

Bars south of Bronks Island dike, built in 1895, seem to have increased considerably in area since that time. In 1894 the gorge was similar, but not so severe; final dam formed on shoals opposite Stuyvesant light. Probably these shoals have increased by cutting off Schodack channel.

In 1886 a series of gorges formed between Barren Island and Stuyvesant, the final gorge formed in the shoals near Stockport; no severe damage. From 1857 to 1886, a period of twenty-nine years, no gorges formed which appreciably affected the railroad. In 1857 the gorge formed between Castleton and Overslaugh dike and did considerable damage.

It would seem that higher water is caused by cutting off minor channels and lessening cross section of river, and that gorges form almost annually in main channel between the dikes, due to minor freshets and swift currents in contracted channel. These two conditions are pronounced between Castleton and Barren Island.

The formation of extensive bars at southern end of dikes offers obstruction to the flow after gorges break. This is noticeable between the south end of Houghtailing Island and Nutten Hook, also below the mouth of Stockport Creek, where a deposit has been made under similar conditions but from different causes.

Exhibit 2 shows that gorges have increased in number and severity with dike construction. Is this a relation or simply a coincidence? Remedy: Reservoirs and forest development in upper Hudson and Mohawk Valley and straightening and otherwise improving the Hudson River.

*Mr. Joel Nelson, justice of the peace, New Baltimore.*—The little dike north of Lamp Island causes in a freshet a swift current to the westward, striking near McCabe's ice house. Remedy: It's removal.

*Mr. Ulster Davis, of Albany, N. Y.*—At several places bars have been left in the channel radius of these dikes, namely:

(a) Cuyler bar, at north end of Van Rensselaer Island and extending to below Douws Point.

(b) Opposite Staats, where ice is now gorged to the bottom between Van Wies Point and Staats, forcing everything to the eastward.

(c) Cedar Hill to Castleton, ice is gorged now to the bottom, to the westward of channel.

(d) Mulls bar, where present gorge is formed, having gorged on bar on east side of channel and run off to westward.

(e) New Baltimore, due to dike on east side. This dike and shoal at Lamp Island should be removed.

Dikes confine the current and ice, forcing the ice to the bottom and forming dams.

Depletion of forests of the watershed and sudden thaws cause rise in the river. Suggestions:

(a) Restrain water in Mohawk by dams and reservoirs.

(b) Have ice-breaking boats from December to April.

(c) Break up ice from Catskill to Albany.

(d) Restrict timber cutting.

Makes offer ice boat, December 1 to April 1, $20,000 per year.

*Mr. Dexter Hunter.*—Remove obstructions at Coeymans. Calls attention to improvements at Albany; filling in of basin has bad effect.

*Mr. A. S. Van Derger, Coeymans, N. Y.*—Remove all dikes and obstructions.

*Mr. Andrew Colvin, of Albany, N. Y.*, appeared before the Board. Says that gorges are formed at Van Wies Point, Cedar Hill, Mulls Cross-over, opposite Upper Schodack Island, Coeymans, Stonehouse bar. Strongly wishes to remove or modify the spur dike at Lamp Island, opposite New Baltimore, and to correct Stonehouse bar below Houghtailing Island.

It appears from the above abstracts that only two parties speak unfavorably of the dike system of improvements, viz, Mr. W. E. Scott, of Castleton, and the New York Central and Hudson River Railroad. All the other parties interested in this matter do not attribute the gorges to the dikes, nor do they think there is any connection between them. The New York Central and Hudson River Railroad tracks have a general elevation above low water of 31 feet at the Albany bridge, 20 feet at Greenbush, 15.3 feet at a point 1½ miles above Castleton, 12.6 feet at Castleton, and 9 feet at Stuyvesant.

The report of the committee on freshets in the Hudson River, December, 1902 (see Appendix 3[a]), was laid before the Board by Mr. William B. Jones, secretary of the above committee (see Appendix 2[a]). This report describes especially the freshets in the Hudson of 1900 and 1902 and gives a description and photographs[a] of the flooded districts of Troy, Watervliet, Rensselaer, Castleton, Coeymans, and New Baltimore. The freshet of 1902 did the greatest damage in Albany, and as a result 109 wholesale houses, 95 stores, and 123 other places of business were closed; 67 factories were shut down, the water in some instances reaching a depth of 3 and 4 feet. Nearly 3,600 families were also driven entirely or partly from their homes. The lines of the New York Central and Hudson River Railroad from Albany to Stuyvesant were submerged and piled in many places high with ice. The maps[a] opposite pages 17 and 28 of Appendix 3 show the inundated areas of Albany, Rensselaer, and Watervliet in 1902.

The report of the New York State water storage commission, January, 1903 (see Appendix 3), was laid before the Board. The duties of the commission were to make at once "such surveys and investigations as may be proper to determine the causes of the overflow of the various rivers and water courses of the State, and to determine if anything can be done to prevent such overflow." For systematic work the State was divided into four divisions, and reported as follows, viz:

*Division No. 1.*—Western district, bounded easterly by a line between the watersheds of several finger lakes and that of Genesee River, the Chemung River, and Susquehanna River, including all of the section west of the division line.

*Division No. 2.*—Central division, embracing Oswego River, watersheds of finger lakes and Seneca and Oneida rivers, and watersheds of Susquehanna and Delaware rivers and tributaries in State.

[a] Not printed.

*Division No. 3.*—Eastern division, Hudson and Mohawk, and tributaries.
*Division No. 4.*—Northern division, Champlain, St. Lawrence, Black, and Salmon rivers, and tributaries.

Owing to short time and meager appropriation, only general information could be obtained. The preliminary cause of floods is irregularity in rainfall. The divisional reports show that most of streams can be regulated by storing their flood waters in reservoirs. Where possible, this method has advantages over channel improvement. Besides preventing freshets, regulation by storage has benefit to public health, navigation, reclaiming marshes, and development of power. The Hudson River above Troy gives a striking illustration of value of water storage for power. It has watershed of 4,500 square miles, maximum flow of 60,000 cubic feet, and a minimum flow of less than 1,500 cubic feet, per second; 70,000 horsepower now developed.

The denudation of forests has intensified freshet conditions. Experience here and abroad has shown that no improvement of a river by diking, straightening, or enlarging can safely be undertaken except by treating the river as a whole from source to mouth, and that storage required to prevent floods be distributed ratably upon all the tributaries according to area of their respective watersheds. Favor State supervision and control.

Subsequent to the public hearing on January 28, 1903, the following additional papers[a] were received by the Board (see Appendix 4), viz:

(*a*) Report presented by Mr. William B. Jones, secretary of the committee on freshets of the Albany Chamber of Commerce, on the attempt in March, 1903, to open up a channel through the ice, and to break up a gorge by means of armored boats. (See Appendix 4a.)

(*b*) Letter from Mr. W. J. Wilgus, fifth vice-president of the New York Central and Hudson River Railroad, dated March 6, 1903, stating the need of opening up Schodack Creek and other side channels, and rectification of the river below Castleton. Incloses photographs D, D2, E, F, and F2, illustrating the gorges of March, 1903. (See Appendix 4b.)

(*c*) Letter and petition from the citizens of Castleton, N. Y., dated February 3, 1903. (See Appendix 4c.)

## CONCLUSIONS.

The Hudson River, up to the State dam at Troy, is a tidal stream subject to a mean tidal range of about 2.05 feet at the State dam and 2.81 feet at Albany. Fresh water extends from Troy to the vicinity of Poughkeepsie at ordinary stages in the upper river; thence to the sea saline matter is evident.

As shown in this report, the velocities of the currents in the upper portion of the tidal estuary of the Hudson are ordinarily less than 2 miles an hour. The maximum velocities rarely exceed 4 miles per hour. The tide ebbs and flows approximately six hours in each direction at low water, and it is only at the time of freshets that the periods of ebb materially exceed in duration the periods of flood.

It thus follows that ice forming in this portion of the river or brought down over the State dam from its nontidal tributaries is carried back and forth through short distances near the head of the estuary, by the ebb and flow of the tide, as modified by the freshwater inflow. It can not be carried by the current to the mouth of the river until very great discharges from the drainage area of the Hudson exceed in volume the flood tide, and thus produce a marked resultant flow seaward. The ordinary condition at even moderate freshets is a movement backward and forward, confined to a short range, not exceeding 10 to 15 miles. The ice is finally congealed and solidified from shore to shore and becomes fixed in position. The Hudson below Albany is then "frozen over." This usually occurs some time

[a] Not printed.

after freezing weather sets in along the upper nontidal river and its tributaries, or late in November or in December, when the fresh-water discharge is near the minimum volume.

During winter the river is usually frozen solid from near Poughkeepsie to Coxsackie, or even to the State dam. A thaw or slight freshet then setting in will produce a rapid rise in the shallow part of the estuary and may partially break up the ice and project it against a field of ice over the deeper water below. These fields are much less affected by the rise and have vertical motion only. The additional ice brought down from the nontidal tributaries increases the amount already afloat in this short stretch.

Now, when the river is in this condition, this ice accumulates and encountering the unbroken field below is in part packed against it or on top of it, and in part tilted by the current and carried beneath it, and soon a small ice pack more or less engorges the stream.

The upper shallow part of the estuary, then, is simply a receptacle for not only the ice forming upon it, but also of all ice passing over the Troy dam from above. It can not escape to the sea until the ice fields below break up and are carried out by great freshets, and consequently, whenever the supply of such ice becomes great, it must inevitably pile up and fill the shallow channels and cause a gorge. A primary gorge is then formed which may not cause any material rise or "freshet" at the time, but which daily becomes more solidly compacted by congelation and strengthened by freezing of the main river at and below it.

If now there is a partial or complete break-up of the ice in the nontidal streams, and this ice is forced down over the dam, then this primary or incomplete gorge is likely to determine a formidable gorge and a dangerous rise in the water surface above it. Such rise, whether occasioned by a gorge or otherwise, is called a "freshet" on the Hudson.

It is evident that the lodging of the ice is also influenced as follows:

(*a*) In shallow water, such as at channel crossings where a submerged bar exists on the downstream side of the crossing, with a similar bar on the opposite side, the ice first reaches or grounds on the bar in shallow water, builds upstream, then swings around its fixed end, and if its free side grounds on the opposite bar it may form an arch across the channel. Additional floating ice from above lodges against it, piles on top or dives beneath, and congeals against the ice above it. Finally, the obstruction becomes more or less complete, and unless broken may cause a gorge after any break-up in ice fields above the dam.

(*b*) A floating mass of ice from a broken primary gorge above may be caught in a more narrow or obstructed part of the river below and determine a greater gorge of more damaging character than the primary. The locus is usually determined by shallow water in crooked channels or crossings.

(*c*) Ice men in harvesting ice force cakes of worthless ice beneath the surface ice, and these pieces become congealed to surface ice or lodge on the ground, and a nucleus of a gorge is then formed when there is no other floating ice to tilt, pass under the surface and build downward toward the bottom as above described. This may be a prolific cause of gorges by materially increasing the thickness of ice beyond natural limits.

(*d*) Many gorges have been determined in position by the bridges with comparatively narrow openings at or near Albany. The records show four gorges at this locality.

The primary gorges have usually, when not at bridges, formed at natural obstructions, such as bars, cross-overs, and bends, at stages of the river when its surface was below the crest of the dikes. Occasionally gorges have formed, as shown by the map[a] herewith, in the vicinity of dikes, but there are apparent, as a rule, other causes than the dikes. The Board is of the opinion that in certain places additional dikes would materially better existing conditions, and at some places where inferior channels are cut off at ordinary tides by dikes at their heads, that conditions as regards formation of gorges might be improved by raising the dikes, if not up to freshet stages, at least to the level of the ground surface of adjacent islands. This would prevent lateral drift of ice over them into shallow water with resulting ice packs that build up and react toward the channels or on rises pass out of the inferior channels and lodge on bars immediately below.

The cutting down of the forests and the general conditions at time of rainfall are also great factors in the cause of gorges, as the rain water is not absorbed in frozen ground, but immediately runs off to the streams, thus causing, at first, movements of the ice which forms gorges and then the freshet itself. In this connection it should be noted that freshets of great magnitude have occurred late in the spring when ice and gorges had completely disappeared.

Briefly stated, the efficient cause of gorges is the projection of floating ice from streams moving ever in one direction into the head of a tidal estuary against ice fields moving only in a vertical direction or with the tide. So long as the head of the estuary is of such dimensions that the foreign ice is more than sufficient in quantity to fill the channels and unduly restrict the flow of water, gorges must inevitably form, whatever the shape of the channels. Such gorges or dams of ice can be prevented—

(*a*) By enlarging the tidal channels to such dimensions and depths that the foreign ice may be provided for near the head of the estuary and still leave room for the natural discharge under it. This method is expensive, if not absolutely impracticable.

(*b*) By impounding the flood waters of the upper tributaries in huge reservoirs. This method, while insuring some success, would be prohibitive as to cost, while always exposing the cities below to great danger of sudden flood.

The use of ice-breaking boats may aid in reducing the height of a freshet, provided they can be brought into timely service below the gorge. Their use is, however, limited to such periods when the freshet has gained some height and causes a decided downstream current. They can not, however, work against a great head of water, and only with difficulty below a gorge in a reach more or less solidly frozen.

It must be kept clearly in mind that nearly all the property injured by freshets and ice, including the tracks of the New York Central Railroad Company, is constructed or founded on land well known to be subject to overflow, not only by ice, but by freshets when no ice is running. Some of the highest freshets occurred before any of this property existed, and the owners thereof must have been aware of the

[a] Not printed.

risks assumed by them when they so constructed their buildings and roads. Even now, in the opinion of this Board, a safe and not impracticable method of escaping damage from such natural visitations is by raising all such exposed structures above the known limits of high water and ice, whether the expense be borne by the State or by individuals.

A study of the gorges heretofore reported does not result in adducing any facts that would lead the Board to think that the dikes for the river improvement have had any injurious effect in the creation of ice gorges. On the contrary, the more regular and deeper channels made by their aid, and their action as training walls in deflecting the ice into less obstructed channels, improve the capacity of the stream to carry ice without engorgement. The channels are, moreover, defined by nearly vertical dikes with much deeper water against them than in the natural condition of the stream. It does not appear that the dikes have either directly or indirectly caused the gorges. There were freshets with gorges before the dike improvement began and there have been freshets with and without gorges since the dikes were built, and their increasing frequency is a natural consequence of cultivation and deforestation. The Board in its examination of the dikes found no evidence of any strain or serious damage due to contact with ice. The dikes were in many cases built many years ago and are still in good condition, which could not be the case had they offered any substantial resistance to the movement of the ice.

The Board considers that the existing Government work in connection with the upper Hudson improvement has not only not caused gorges and freshets between Albany and Coxsackie, but that it has been an aid in diminishing them, and the Board is of opinion that the diking system should be extended to carry the channel over the bars and to deepen and straighten the channel throughout the entire course from the State dam to Coxsackie. The Board recommends that the following modifications in the channel improvements be made on the reach of the Hudson River between Albany and Coxsackie.

| | |
|---|---|
| 1. Removal of 200 feet of south end of middle dike at Coeymans, in order to allow egress for the waters and ice behind the dike | $3,000 |
| 2. Extension of lower arm of Willow Island dike to the north, to avoid the sharp bend in the present dike and reduce the deflection of the current toward New Baltimore, 600 linear feet | 8,500 |
| 3. About 1,800 feet of rubble dike opposite Clifford's ice house, Upper Schodack Island, should be cribbed to reduce friction for floating ice | 10,000 |
| 4. Dredging at Stonehouse bar, 290,000 cubic yards | 81,500 |
| Total | 103,000 |
| Add 10 per cent contingencies | 10,300 |
| Total | 113,300 |

The Board considers that these improvements will remove some of the local objections to the dikes, which have been subject to criticism, but the Board is further of the opinion that gorges and freshets can not be completely overcome by any practicable rectification or deepening the river.

There is forwarded herewith a tracing[a] showing the channels according to the latest surveys. The dikes, bars, cross-overs, location of gorges, etc., are also indicated.

[a] Not printed.

The papers enumerated below accompany this report as appendixes:[a]

1. Stenographer's report and papers received at the public hearing held in Albany, January 28, 1903.
2. Report of committee of the Albany Chamber of Commerce on freshets in the Hudson River, December, 1902.
3. Report of the New York State water storage commission, January, 1903.
4. Papers received subsequent to the public hearing.

Respectfully submitted.

W. L. MARSHALL,
*Major, Corps of Engineers.*
EDWARD H. SCHULZ,
*First Lieut., Corps of Engineers.*

Brig. Gen. G. L. GILLESPIE,
*Chief of Engineers, U. S. A.*

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[a] Not printed.

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